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Field Evaluation of Fungicides and Biocontrol Agents for Managing False Smut Disease in Rice incited by *Ustilaginoidea virens* (Cke) Tak

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ABSTRACT

Rice false smut, caused by *Ustilaginoidea virens* (Cooke) Takahashi, is an economically significant disease affecting rice cultivation globally, including in India. In India, yield losses due to this disease have been reported to range from 0.5% to 49%, depending on the rice cultivar and prevailing environmental conditions. The present study was undertaken to evaluate the efficacy of selected fungicides and biological control agents for the management of false smut under field conditions. Among the fungicidal treatments, foliar application of Propiconazole (0.1%) followed by Trifloxystrobin + Tebuconazole (0.04%) at the booting stage was found to be the most effective in significantly reducing the number of infected tillers and smut balls per panicle. This treatment also resulted in a notable increase in grain yield and test weight. The treatment Kresoxim methyl @ 0.1% was not found much effective to control the disease. Among the bioagents tested, *Bacillus subtilis* demonstrated the highest effectiveness in disease suppression, followed by *Pseudomonas fluorescens* and *Trichoderma viride.* These findings indicate that both chemical and biological approaches can be successfully integrated for effective management of rice false smut under field conditions.

Keywords Rice,Damini. False smut,Fungicide, Bio-control agents.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the primary staple for more than half of the global population (Birla *et al.* 2017). India ranks as the world's second largest producer at approximately 152.6 million tonnes (Statista 2023). The major rice producing states are Uttar Pradesh, Telangana, West Bengal, Punjab, Chattisgarh and Odisha. In Uttar Pradesh, it is cultivated in an area of 5.90Mha with production of 16.14 MT and average productivity 2723 kg/ha (Anonymous 2023). Despite

advances in agronomic practices and cultivar development, rice productivity is continually threatened by numerous biotic stresses. Among these, false smut-caused by the fungal pathogen Ustilaginoidea virens (Cooke) Takahashi is emerging as one of the most devastating diseases in major rice growing regions, including India, China and USA (Sun *et al.* 2020).

U. virens infects rice during the booting to flowering stages, converting individual florets into spherical, velvety spore balls that range in color from yellow green to dark green upon maturation (Fan *et al.* 2013). Disease development is favored by warm temperatures (25–30 °C), high relative humidity (>80%), late crop establishment, and excessive nitrogen fertilization (Baite *et al.* 2021). Under such conditions, epidemics can lead to widespread incidence, with affected fields exhibiting both reduced grain quality and safety concerns arising from mycotoxin contamination.

Yield losses due to false smut vary widely, with reports ranging from 2.8% to 81% depending on cultivar susceptibility, environmental factors, and disease intensity. In India specifically, losses of up to 49% have been documented under conducive conditions and susceptible genotypes (Molla 2024). In addition to quantitative losses, *U. virens* produces a suite of toxic secondary metabolites including ustiloxins and ustilaginoidins that compromise grain viability, pose risks to livestock and human health, and complicate postharvest management.

Chemical control through targeted fungicide applications remains a cornerstone of false smut management. Foliar sprays at critical growth stages particularly the booting stage have demonstrated substantial reductions in disease incidence and severity. These treatments not only suppressed pathogen development but also enhanced effective tiller number and 1,000 grain weight, translating into significant yield gains.

However, the long-term sustainability of fungicide-based strategies is constrained by concerns over residue accumulation, pathogen resistance development and environmental impact. As a result, biological control agents have received increasing attention as ecofriendly alternatives or complements to chemical fungicides. Bio-agents induce systemic resistance in rice and produce antifungal metabolites that impair pathogen establishment. Therefore, the aim of this study was to evaluate the effectiveness of fungicides and bioagents to manage rice false smut disease of paddy.

MATERIALS AND METHODS

The management experiment was conducted at Students Instructional Farm of A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya during two consecutive years *kharif* 2020-21 and 2021-22.

The experiments were laid out in randomized block design (RBD) with thirteen treatments of three replications. A highly susceptible variety 'Damini' was used to evaluate the treatments against the disease.The treatments include three fungicides and three bio-agents, one non-treated control (Table 1). The plot size was 10 m2 (5 × 2 m), spacing 20 × 15 cm.

Spraying of fungicides and bio-agents

The fungicides and bio-agents (fresh talc-based formulation) were calculated, weighed and spray solution was prepared with water. Each treatment was dissolved in small amount of water and then volume was made up to desired level and was sprayed by using high volume Knapsack sprayer of 15 liter capacity. One spraying of each fungicide was applied at two crop stages, one at booting stage and second

Table 1. Treatment detail.

Treatments	Crop stage
Trifloxystrobin 25% + Tebuconazole 50% @ 0.04%	T_1 Booting T_2 100 % PE
Kresoxim methyl @ 0.1%	T_3 Booting T_4 100 % PE
Propiconazole @ 0.1%	T_5 Booting T_6 100 % PE
Trichoderma viride @ 2%	T_7 Booting T_8 100 % PE
Bacillus subtilis @ 2%	T_9 Booting T_{10} 100 % PE
Pseudomonas fluorescens @ 2%	T_{11} Booting T_{12} 100 % PE
Control	

at 100% panicle emergence stage. Observations were taken one week before the harvesting of crop. 1% infected tillers, 2% smutted balls, 3. Yield, and 4. 1000 seed weight.

Yield and test weight

Yield (kg/ha) was recorded in each treatment separately to know the difference in yield between treated and untreated check.

Statistical analysis

All the data for each character under study were statistical analyzed following the procedure of Randomized Block Design (RBD) for field experiment, and calculation were done after applying the test of significance for the treatment means. The data obtained on percentage were transformed in to angular values (Fisher and Yates 1963).

$Sin^{-1}\sqrt{}$Per cent before statistical analysis

RESULTS AND DISCUSSION

Effect of Fungicides and bio-agents against false smut of rice 2020-21 and 2021-22 (pooled)

Effect on per cent infected tillers

It is clear from the Table 2 that the per cent infected tillers were significantly decreased with the application of fungicides and bio-agents over untreated control. Minimum infected tiller was observed in Propiconazole @ 0.1% at both booting and 100% PE stages i.e., T_5 3.43% and T_6 4.72% respectively followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04% (T_1 4.73% and T_2 5.48%), *B. subtilis* @ 2% (T_9 8.58% and T_{10} 9.83%), *P. fluorescens* @ 2% (T_{11} 10.18% and T_{12} 10.75%) and *T. viride* @ 2% (T_7 11.17% and T_8 12.95%). The treatment Kresoxim methyl @ 0.1% was not found much effective and having infected tillers % at both crop stage is T_3 14.21% and T_4 15.69%. The treatment T_6 and T_1¬, T_{10} and T_{11}, T_{12} and T_7 were found at par to each other.

Evaluation of various fungicides and bio-agents for the management of false smut revealed that propiconazole @ 0.1% sprayedat booting and 50% panicle emergence crop growth stage was found most effective in minimizing the incidence and severity of false smut and increase grain yield of rice cultivar Damini followed by trifloxystrobin 25% + tebuconazole 50% @ 0.04%. The disease is managed well when the fungicides/bio-agents sprayed at booting stage. Spray of fungicides/bio-agents at 100% panicle emergence stage was found less effective as compared to sprayed at booting stage. This might be attributed to the fact that infection by *U. virens* does not occur after heading as reported by earlier researchers (Guo *et al.* 2012).

Table 2. Management of false smut disease of paddy caused by *Ustilaginoidea virens* through bio-agents and fungicides cv. Damini during 2020-21 and 2021-22 (pooled data).

Sl. No.	Treatments	Crop stage	% of infected tillers	% decrease in infected tillers	Smutted balls	% decrease in smutted balls
1	Trifloxystrobin 25% + Tebuconazole	Booting	4.73 (12.55)	79.00	0.91 (5.42)	78.73
	50% @ 0.04%	100 % PE	5.48 (13.57)	74.60	1.04 (5.81)	75.70
2	Kresoxim methyl @ 0.1%	Booting	14.21 (22.14)	34.15	2.89 (9.77)	32.47
		100 % PE	15.69 (23.33)	27.29	3.16 (10.23)	26.16
3	Propiconazole @ 0.1%	Booting	3.43 (10.66)	84.10	0.72 (4.79)	83.18
		100 % PE	4.72 (12.54)	78.12	0.97 (5.60)	77.34
4	*Trichoderma viride* @ 2%	Booting	11.17 (19.52)	48.23	2.25 (8.61)	47.43
		100 % PE	12.95 (21.09)	41.66	2.48 (9.04)	42.06
5	*Bacillus* sp. @ 2%	Booting	08.58 (17.03)	60.24	1.31 (6.54)	69.39
		100 % PE	09.83 (18.27)	54.44	1.66 (7.38)	61.21
6	*Pseudomonas fluorescence* @ 2%	Booting	10.18 (18.60)	52.83	1.81 (7.71)	57.71
		100 % PE	10.75 (19.13)	50.18	2.21 (8.53)	48.71
	Control (Water spray)		21.58 (27.68)	-	4.28 (11.93)	-
	CD (P=0.05)		0.54		0.93	
	CV		1.77		7.11	

The results found are in agreement with the findings of Saurabh (2014) as he reported minimum per cent infected tillers was found with treatment Propiconazole @ 0.1% at booting stage as compared to 100% panicle initiation stage followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04 % at both the crop stages. These results were also supported by various researchers (Ladhalakshmi *et al*. 2014, Kumari and Kumar 2015, Ladhalakshmi *et al.* 2018, Tripathi *et al.* 2019, Kumar *et a*l. 2020). Optimum time of application of ergosterol biosynthesis inhibitor (EBI) fungicides has been found effective 1-2 weeks prior heading to control false smut (Tsuda *et al.* 2006). Presently, Kresoxim methyl was not found effective against the disease (Banasode and Hosagoudar 2020). Bioagents (*Trichoderma* sp., *Bacillus* sp. and *Pseudomonas fluorescen*s) was also found effective against the disease (Rashmi 2014 and Cui *et al.* 2019).

Effect on per cent smutted balls

It is clear from the Table 2 that the per cent smutted balls were significantly decreased with the application of fungicides and bio-agents over untreated control. Minimum % smutted balls were observed in Propiconazole @ 0.1% at both booting and 100% PE stages i.e., T_5 0.72% and T_6 0.97% respectively followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04% (T_1 0.91% and T_2 1.04%), *B. subtilis* @ 2% (T_9 1.31% and T_{10} 1.66%), *P. fluorescens* @ 2% (T_{11} 1.81% and T_{12} 2.21%) and *T. viride* @ 2% (T_7 2.25% and T_8 2.48%). The treatment Kresoxim methyl @ 0.1% was not found much effective and having % smutted balls at both crop stages is T_3 2.89% and T_4 3.16%. The treatment T_5, T_1, T_6, T_2 and T_9, T_1, T_6, T_2, T_9, T_{10} and T_{11}; T_9, T_{10}, T_{11} and T_{12}; T_{10}, T_{11}, T_{12}, T_7 and T_8; T_{12} and T_3, T_3 and T_4 were found at par to each other. Similar results were also reported researchers (Ladhalakshmi *et al.* 2014, Ladhalkshmi *et al.* 2018, Tripathi *et al*. 2019, Kumar *et al.* 2020) as he also found minimum number of smut balls in propiconazole treated plot. Kumari and Kumar (2015) found that the when propiconazole sprayed at booting stage of crop then the number of smut balls per panicle was minimum.

Effect on yield (q/ha)

It is clear from the Table 3 that the yield was significantly increased with the application of fungicides and bio-agents over untreated control. Maximum yield was found under Propiconazole @ 0.1% at both stages i.e. T_5 60.67 and T_6 60.06 q/ha which was followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04% (T_1 59.95 and T_2 59.03 q/ha), *B. subtilis* @ 2% (T_9 56.19 and T_{10} 55.31 q/ha), *P. fluorescens* @ 2% (T_{11} 54.92 and T_{12} 54.33 q/ha) and *T.viride* @ 2% (T_7 53.97 and T_8 53.13 q/ha). The treatment Kresoxim methyl @ 0.1% was not found much effective and

Table 3. Effect of different treatments i.e. bio-agents and fungicides on yield and 1000 seed weight against false smut disease of paddy caused by *Ustilaginoidea virens* cv. Damini during 2020-21and 2021-22 (pooled data).

Sl. No.	Treatments	Crop stage	Yield (q/ha)	% increase in yield	1000 seed weight
1	Trifloxystrobin 25% + Tebuconazole 50% @ 0.04%	Booting	59.95	23.66	22.72
		100 % PE	59.03	21.76	22.55
2	Kresoxim methyl @ 0.1%	Booting	52.69	8.68	22.30
		100 % PE	51.92	7.10	22.24
3	Propiconazole @ 0.1%	Booting	60.67	25.14	22.89
		100 % PE	60.06	23.89	22.77
4	*Trichoderma viride* @ 2%	Booting	53.97	11.32	22.36
		100 % PE	53.13	9.59	22.32
5	*Bacillus* sp. @ 2%	Booting	56.19	15.90	22.49
		100 % PE	55.31	14.09	22.44
6	*Pseudomonas fluorescence* @ 2%	Booting	54.92	13.28	22.41
		100 % PE	54.33	12.07	22.39
	Control (Water spray)		48.48	-	22.01
	CD (P=0.05)		0.22		0.18
	CV		0.28		0.38

having yield at both crop stages is T_3 52.69 and T_4 51.92 q/ha. The treatment T_1 and T_6 were found at par to each other. Our results are well corroborated with the findings of (Thakur and Ahmad 2019, Tripathi *et al.* 2019, Singh *et al.* 2020) as they also reported that when propiconazole @ 0.1% applied at booting stage gives maximum yield as compared to late booting stage (Kumari and Kumar 2015).

Effect on 1000 seed weight

It is clear from the Table 3 that the 1000 seed weight were increased with the application of fungicides and bio-agents over untreated control. Maximum 1000 seed weight was found under Propiconazole @ 0.1% at both stages i.e. T_5 22.89g and T_6 22.77g respectively followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04% (T_1 22.72 g and T_2 22.55 g), *B. subtilis* @ 2% (T_9 22.49 g and T_{10} 22.44 g), *P. fluorescens* @ 2% (T_{11} 22.41 g and T_{12} 22.39 g) and *T viride* @ 2% (T_7 22.36 g and T_8 22.32 g). The treatment Kresoxim methyl @ 0.1% was not found much effective and having 1000 seed weight at both crop stages is T_3 22.30 g and T_4 22.24 g. The treatment T_4, T_3, T_8, T_7, T_{12} and T_{11}; T_3, T_8, T_7, T_{12}, T_{11} and T_{10}; T_8, T_7, T_{12}, T_{11},T_{10} and T_9; T_{12}, T_{11},T_{10}, T_9 and T_2; T_2 and T_1; T_1, T_6 and T_5 was found at par to each other. Maximum 1000 seed weight (g) was obtained under treatment propiconazole followed by Trifloxystrobin 25% + Tebuconazole 50%. Similar result was also found by Kumari and Kumar (2015).

CONCLUSION

It is concluded that application of fungicides and bio-agents significantly reduced the incidence of false smut in rice. Propiconazole @ 0.1% applied at booting and 100% panicle emergence stages was most effective in minimizing per cent infected tillers and smutted balls, and enhancing yield and 1000-seed weight, followed by Trifloxystrobin 25% + Tebuconazole 50% @ 0.04%. Kresoxim methyl @ 0.1% was not found much effective to control the disease. Among bio-agents, *Bacillus subtilis* performed better than *Pseudomonas fluorescens* and *Trichoderma viride*. Overall, spraying at booting stage was more effective than at 100% panicle emergence, indicating the importance of timely fungicidal intervention for effective false smut management.

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